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REPORT

CD NO.

COUNTRY	USSR	DATE OF INFORMATION	1950
SUBJECT	Scientific - Geophysics, altimeters		
HOW PUBLISHED	Bimonthly periodical	DATE DIST.	?? Nov 1950
WHERE PUBLISHED	Leningrad	NO. OF PAGES	4
DATE PUBLISHED	May 1950		
LANGUAGE	Russian	SUPPLEMENT TO REPORT NO.	

THIS IS UNEVALUATED INFORMATION

SOURCE Izvestiya Vsesoyuznogo Geograficheskogo Obshchestva, Vol LXXXII, No 3, pp 326-329.

AN ACCURATE ALTIMETER FOR GEOGRAPHICAL STUDIES

E. A. Norman

Toward the end of 1948, Soviet inventor M. A. Artanov designed and produced, with the help of mechanic N. I. Polyashov, a test model of an automatic high-accuracy altimeter. This light, durable, and reliable instrument will be useful to every geographer, geologist, geophysicist, topographer, and geophysical engineer. The altimeter is a differential barometer and differs from all its predecessors in that all its components are designed for rapid and complete consideration for all free air temperature changes. This new principle in the design of differential barometers and the original construction of components greatly simplifies field observations and office processing of results. The difference in height of one point of a locale with respect to another can be determined in less than a minute, i.e., immediately on taking the readings from the scales of the instrument.

From 1937 to 1940, several differential barometer models were constructed in the Central Scientific-Research Institute of Geodesy, Aerial Surveying, and Cartography, using a glass vessel with aneroid walls with a glass air box inside it. These repeated attempts, however, to construct an instrument on the Mendeleyev principle of maximum temperature insulation of the air box from free air temperature changes did not produce satisfactory results, mainly because absolute temperature insulation could not be obtained in a portable instrument even with the help of glass vessels with aneroid walls. Thus, the air temperature in the box still varied and temperature corrections had to be introduced into the readings. This factor, along with the fragility of the instruments, made them very difficult to handle in the field.

The fifth model of an M. A. Artanov altimeter was designed on a completely different principle. All components of the altimeter were designed for rapid and complete consideration for all free-air temperature changes in such a way that the rate of change of air temperature in the air box A (see appended figure) is equal to the rate of change of free-air temperature.

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The altimeter is designed to determine the relative height differences of two contours for both positive and negative free-air temperatures. It is very durable and always ready for use without preliminary operations and can be transported in any position. The altimeter automatically makes a correction for a temperature change of the air in the air box and a correction for a temperature change of the liquid G in the manometer tubes V and N. This design problem was solved by the use of a metallic air box, surrounded by a thin layer of nonfreezing liquid G having certain definite physical properties. This liquid layer is at the same time a reservoir of the differential thermometer D. This is the main distinguishing feature of the altimeter.

Air box A is in contact with the atmosphere through the tube I and can be isolated from the atmosphere by means of the stopcock E. The manometer tubes V and N are connected with the air box A and are partially filled with the nonfreezing liquid. The upper end of the manometer tube N is in contact with the atmosphere. There is nonfreezing liquid between the walls of the boxes A and M and in the thermometer tube B. This liquid is at the same level in the tubes D and Zh when the stopcock B is open. When the stopcock E is open, the liquid in manometer tubes V and N is at the same level. When the stopcock is closed, equilibrium of the liquid in the tubes V and N is not violated if the pressure in the box A is the same as atmospheric pressure. When the stopcock E is closed and the temperature of the air in the box and of atmospheric air is the same, the liquid in the tubes V and N will be displaced to one side or the other when the atmospheric pressure changes.

The dependence of the height of the liquid columns in the manometer tubes V and N on a change of external pressure is determined by the well-known physical law, $\frac{vP_1}{T_1} = \frac{(v+\Delta)(P_2+m)}{T_2}$ where v is the initial volume of air in the box, P_1 the pressure (mm/Hg) corresponding to the starting point, T_1 the temperature of the air in the box (figured from absolute zero) corresponding to the starting pressure, delta Δ the increment of the volume of air in the box, P_2 the pressure at the next point, m the height of the liquid column in the manometer tube (mm/Hg), and T_2 the temperature of the air in the box corresponding to the pressure P_2 at the next point (figured from absolute zero).

Starting from the basic relationship above, the inventor derived a formula for calculating the difference of levels of the liquid in manometer tubes V and N, namely,

$$\ell = \sqrt{\left(\frac{P_2}{k} + \frac{2v}{s}\right)^2 - \frac{2v}{sk}\left(P_2 - P_1\frac{T_2}{T_1}\right)} - \left(\frac{P_2}{k} + \frac{2v}{s}\right);$$

where ℓ is the difference of levels of the liquid (mm), k the ratio of the density of the liquid to the density of mercury at the given temperature, and s the transverse cross-sectional area of manometer tubes V and N.

The elements of the altimeter are designed according to the above formula so that the increase of heights of the manometer and thermometer columns is approximately equal for an equal variation of the temperature of the air and liquid in the boxes when the external pressure does not change. Thus, the difference between the heights of these columns indicates the pressure increase at the given observation point with a correction for change of air temperature in the box automatically included in the readings from the scales of the instrument.

The implementation of these theoretical considerations in construction was a very difficult technical problem, solved only after 6 years of experiments by the use of certain necessary materials and special construction of parts.

The instrument has three scales, two manometer and one thermometer. All scales are graduated in meters of the real excesses. At the first station, the liquid columns in the tubes D, Zh, V, and N are leveled off for the given barometric degree by opening and then closing the stopcocks B and E. Then the observer takes readings from all three scales for this first and each succeeding station. The increase of height of one point above another is determined by a few simple arithmetic operations. For example, given the readings:

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No of Station	Time of Observation Hr	Min	Location of Station	Readings from Scales First	Second	Third
21	11	15	Sedlovina A	120.3	79.7	100.0
22	11	51	Mouth of a stream	84.2	115.8	55.1
23	12	25	Top of a hill	162.7	37.3	26.9
Datum Point 14	12	42	Sedlovina B	132.4	67.6	52.5

Taking the readings from the second and third scale always with a minus sign, we calculate the increase of points 21, 22, 23 and datum point No 14 over some zero (for the given barometric degree) point X:

No 21..........120.3 - 79.7 - 100.0 = -59.4 meters
No 22.......... 84.2 - 115.8 - 55.1 = -86.7 meters
No 23..........162.7 - 37.3 - 26.9 = +98.5 meters
Datum Point 14......132.4 - 67.6 - 52.5 = +12.3 meters

Let us assume that the absolute (or provisional) reading for datum point No 14 is 102.7 meters. The unconnected absolute (or provisional) marks for the above three stations will then be equal to:

No 21..........102.7 - 12.3 - 59.4 = 31.0 meters
No 22..........102.7 - 12.3 - 86.7 = 3.7 meters
No 23..........102.7 - 12.3 - 98.5 = =188.9 meters

The scales of this altimeter are designed for execution of field work without any corrections when atmospheric pressure is within the limits 760-740 mm and when free-air temperature varies from 15 to 25°C. When field work is carried out under other atmospheric pressures or free-air temperatures, a correction must be made in the height increases found by the above method.

The altimeter can be used to determine relative heights ± 200 meters from the height of the first station if there are no major changes of atmospheric pressure and free air temperature. Greater height differences are determined in stages.

The dimensions of the altimeter are 7 x 7 x 27 cm and its weight, 900 grams. The cost is about 300 rubles when the instruments are mass-produced. This altimeter can be gainfully used by expeditionary squads of the Academy of Sciences USSR, the Ministries of Geology, Petroleum Industry, and Transportation, the Main Administration of Geodesy and Cartography, the Military-Topographical Administration, the Main Administration of the Northern Sea Route, and others in geographical, geological, and geophysical studies, various engineering surveys, and works on the height interpretation of aerial photographs.

For this altimeter, M. A. Artanov was given Certificate of Authorship No 382077 - IV in class 42k, 27 July 1948. Previously, 6 June 1942, he had been given Certificate of Authorship No 7179 (309678) for his gas barometer.

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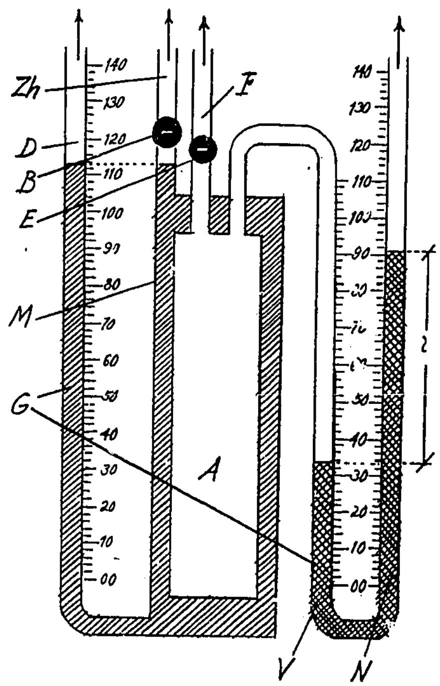
Schematic Diagram of the M. A. Artanov Altimeter



A, metallic air box; B, stopcock; V, manometer tube; G, nonfreezing liquid, D, thermometer tube; E, stopcock; Zh, tube; I, tube; M, metallic box; N, manometer tube

- E N D -

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